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Separation of Cast and Wrought Aluminum Alloys by Thermomechanical Processing

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CONTENTS

	Page
Abstract	1
Introduction	2
Procedure	3
Results and discussion	5
Summary	10
References	12

ILLUSTRATIONS

1.	Process flow sheet	2
2.	Drop-test furnace	4
3.	Flow sheet showing results of hot-crush processing at 540° C	9
4.	Wrought and cast products	11

TABLES

1.	Composition of secondary aluminum casting alloys tested	3
2.	Hand characterization of scrap aluminum separated from reject nonferrous fraction	5
3.	Results of hammer mill tests using casting alloys	6
4.	Results of drop tests using alloy 380	7
5.	Size distribution of cast aluminum after single-stage processing	7
6.	Size distribution of original plus 1-in cast aluminum versus processing temperature	8
7.	Distribution of hot-crush products from each 100 lb of aluminum concentrate	8
8.	Chemical composition of products after single-stage processing	9
9.	Chemical analysis of cast alloy product from multiple-stage processing	9
10.	Copper content of cast fraction product from multiple-stage processing	10

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius	in	inch
ft	foot	lb	pound
h	hour	pct	percent
hp	horsepower	wt pct	weight percent

SEPARATION OF CAST AND WROUGHT ALUMINUM ALLOYS BY THERMOMECHANICAL PROCESSING

By R. D. Brown, Jr.,[1] F. Ambrose,[2] and D. Montagna[3]

ABSTRACT

There are techniques for separating aluminum alloys from mixed scrap, but there are no efficient ways to separate wrought aluminum from cast aluminum. This Bureau of Mines report describes a novel technique for separating mixed aluminum alloy scrap into cast and wrought aluminum alloy fractions. The technique, which uses conventional heating, fragmentizing, and screening equipment, exploits differences in the mechanical properties of cast and wrought aluminum alloys at elevated temperatures. The cast alloys become brittle at high temperatures owing to intergranular melting of regions of eutectic composition. This melting begins to occur as the solidus temperature for each alloy is reached. Solidus temperatures for casting alloys generally range from 520° to 580° C, but are above 600° C for most wrought alloys. Thus, the casting alloys are easily fragmented while the wrought alloys remain ductile in the proper temperature range. Starting with a mixture containing approximately 80 pct cast and 20 pct wrought alloys, fractions of 100 pct cast and 98 pct wrought have been produced.

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INTRODUCTION

In 1983, approximately 1.7 billion pounds of aluminum alloys (old scrap) were recycled in the United States (1).[4] This amount, however, represents only an estimated 30 pct of the total recycling potential. Forty percent of the amount recycled usually is attributed to the transportation sector (2).

Recycling of scrap aluminum[5] poses several technical problems to the secondary ingot maker. Because of its high chemical activity, aluminum cannot be refined by pyrometallurgical techniques such as those used for scrap copper or iron. Therefore, the recycling of mixed aluminum scrap into a specific alloy is accomplished through blending and dilution (3). Wrought alloys contain low percentages of alloying elements; that is, alloying elements total less than about 4 pct. Casting alloys contain the same elements as wrought, but in greater amounts; for example, the silicon content in cast alloys can range up to 22 pct. Due to the tight compositional limits for wrought alloys, the secondary aluminum industry remains primarily a supplier of casting alloys. Exclusive of can recycling, which represents the special case of a source-separated scrap, in 1983, 79 pct of secondary aluminum production was used for casting alloys, 14 pct for wrought extrusion billets, 4 pct for steel deoxidizers, and 3 pct for miscellaneous uses, including aluminum-base hardeners (1).

The use of scrap separation techniques based on water elutriation, heavy-medium, and eddy-current technologies has succeeded in producing suitable aluminum alloy concentrates for recycling from such diverse sources as automobile shredders, municipal solid-waste-processing plants, and municipal incinerators (4). Aluminum concentrates from these sources are mixtures of cast and wrought aluminum alloys and therefore are not suitable for use in wrought alloy production in current practice. This is unfortunate since aluminum scrap entering the recycling stream contains steadily increasing amounts of wrought alloys. The wrought fraction of these mixtures has a value averaging 3 to 5 cents per pound higher when separated (5), and its reuse as wrought alloys would prevent unnecessary downgrading.

Most aluminum casting alloys undergo a catastrophic loss of mechanical properties (tensile, impact, shear strength, etc.) in the temperature range from 520° to 590° C. In comparison, wrought aluminum alloys retain their mechanical properties and remain ductile within this temperature range. Heating a mixture of cast and wrought aluminum alloys to a temperature where the intergranular eutectic region of cast alloy components softens or melts results in the breaking up of cast alloys when modest forces are applied. The wrought alloys remain relatively ductile at these temperatures, retaining their approximate shape and size when subjected to the same forces. As shown in figure 1, screening of the "hot-crushed" mixed scrap completes the

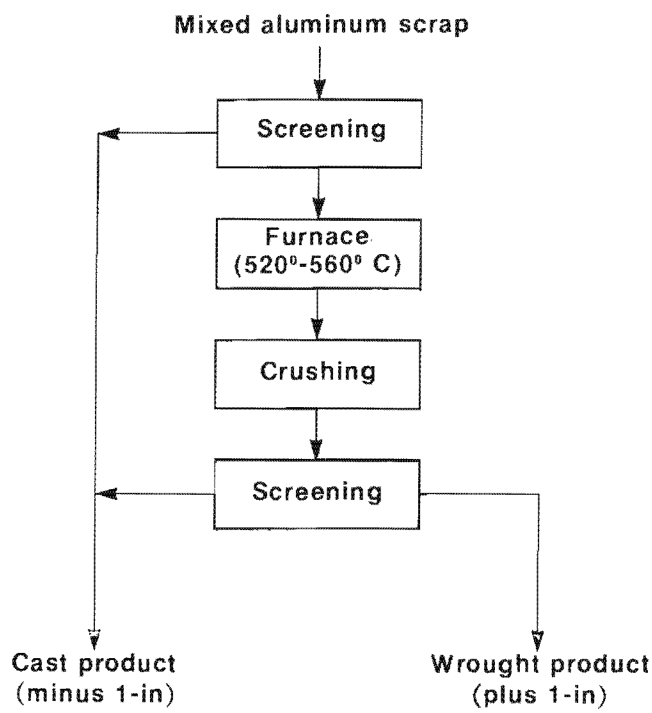

FIGURE 1. - Process flow sheet.

[4] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

[5] Throughout this report, the terms "aluminum" and "aluminum alloys" are used synonymously.

process by collecting the fractured cast alloys as the screen undersize product and the wrought alloys as the screen oversize product (6-7). This report summarizes the Bureau's research and describes the thermomechanical process devised for separating wrought and cast alloys.

PROCEDURE

Preliminary tests were conducted to determine the overall effect of elevated temperature on typical cast and wrought aluminum alloys. Qualitative tests on scrap aluminum, obtained from an automobile shredder, demonstrated that there is a well-defined temperature range where casting alloys lose their ductility and become brittle while wrought alloys remain ductile. In initial tests, pieces of aluminum were heated in the temperature range from 550° to 580° C in a small electric resistance pot furnace and then dropped into a laboratory jaw crusher. The temperature of the metal samples was monitored during heating by a standard K-type thermocouple (Chromel-Alumel).[6] The initial tests showed that the method did have merit. Cast metal fragmented into smaller pieces while wrought metal passing through the crusher was only plastically deformed.

Subsequent tests were conducted to determine the effects of soak time and temperature on a series of cast aluminum alloys of known composition. Ingots were obtained from a major supplier of aluminum, and test specimens, measuring approximately 3/4 by 2 by 3 in, were cut from each ingot. The samples were heated in the same electric resistance pot furnace used previously, but were fragmented in a laboratory hammer mill having a 5-hp drive. Cast aluminum alloys tested were 208, 319, 360, 380, and 413 (table 1). Soak times of 20, 40, and 60 min at temperatures of 540°, 560°, 580° C were investigated. Tests were also conducted at 590° C for 40 and 60 min and at 600° C for 20 and 60 min.

An exploratory series of drop tests was made to determine the relative importance of impact energy and soak temperature in fragmenting casting alloys. These tests provided a simulation of repeated impacts such as might occur if both the heating and crushing were accomplished in a rotary kiln with internal lifting vanes. Three test samples about 3 in by 3 in weighing from 0.13 to 0.20 lb, were cut from a single automotive transmission housing of aluminum alloy 380. The choice of this material was based on the high volume of aluminum alloy 380 currently used for many applications. Each sample was heated in a vertically wound electric resistance furnace. The furnace was equipped with a rectangular steel tube 44-in tall with a 5- by 6-in cross section and a hinged gate, positionable at levels of 2 and 3 ft above the furnace floor (fig. 2). A sample was placed on the gate, heated, and then dropped onto the floor of the furnace. Temperatures tested were 515° to 560° C at 15° intervals. Each sample was held at the

[6]Reference to specific products does not imply endorsement by the Bureau of Mines.

TABLE 1. - Composition of secondary aluminum casting alloys tested

Alloy designation	Solidus temp., °C, (8)	Concentration, wt pct[1]										
		Cu	Fe	Si	Mn	Mg	Zn	Ni	Cr	Ti	Sn	Pb
319.......	516	3.83	0.87	5.64	0.30	0.07	1.00	0.08	0.07	0.09	0.03	0.07
208.......	521	3.91	.97	3.49	.30	.05	.92	.07	.09	.11	.02	.05
380.......	538	3.30	.88	8.40	.23	.07	2.35	.08	.08	.03	.09	.10
360.......	557	.60	.68	9.80	.21	.60	.34	.02	.08	.02	.02	.05
413.......	574	.36	.60	12.20	.12	.09	.32	.03	.04	.03	.02	.04

[1]Certificate of analysis provided by supplying vendor.

desired temperature for 1 h to ensure uniform heating. After dropping the heated sample of aluminum alloy, the resulting material was transferred to a 1-in screen. The plus 1-in portion was reheated for another hour and dropped again. Each sample was cycled five times in the manner described or until the entire sample passed through the 1-in screen, whichever came first.

Large-Scale Tests

A series of larger scale tests was made using 1,500 lb of scrap aluminum (from nonferrous rejects) obtained from an automobile shredder. These tests were to (1) establish if there are any relationships between final product size, soak temperature, and/or soak time at temperature, and (2) determine what level of upgrading can be expected from typical mixed cast and wrought aluminum scrap concentrates. The material was divided into five fractions, each of which was hand sorted using visual observation and screening (table 2). The cast pieces were chunky, dull, and had brittle fractures; the wrought pieces were flat, shiny, and more ductile. The portion of this scrap that was less than 1 in was almost totally devoid of wrought alloys. This indicates that initial upgrading of the reject scrap from the automobile shredder by screening, as shown in figure 1, can reduce the volume of mixed

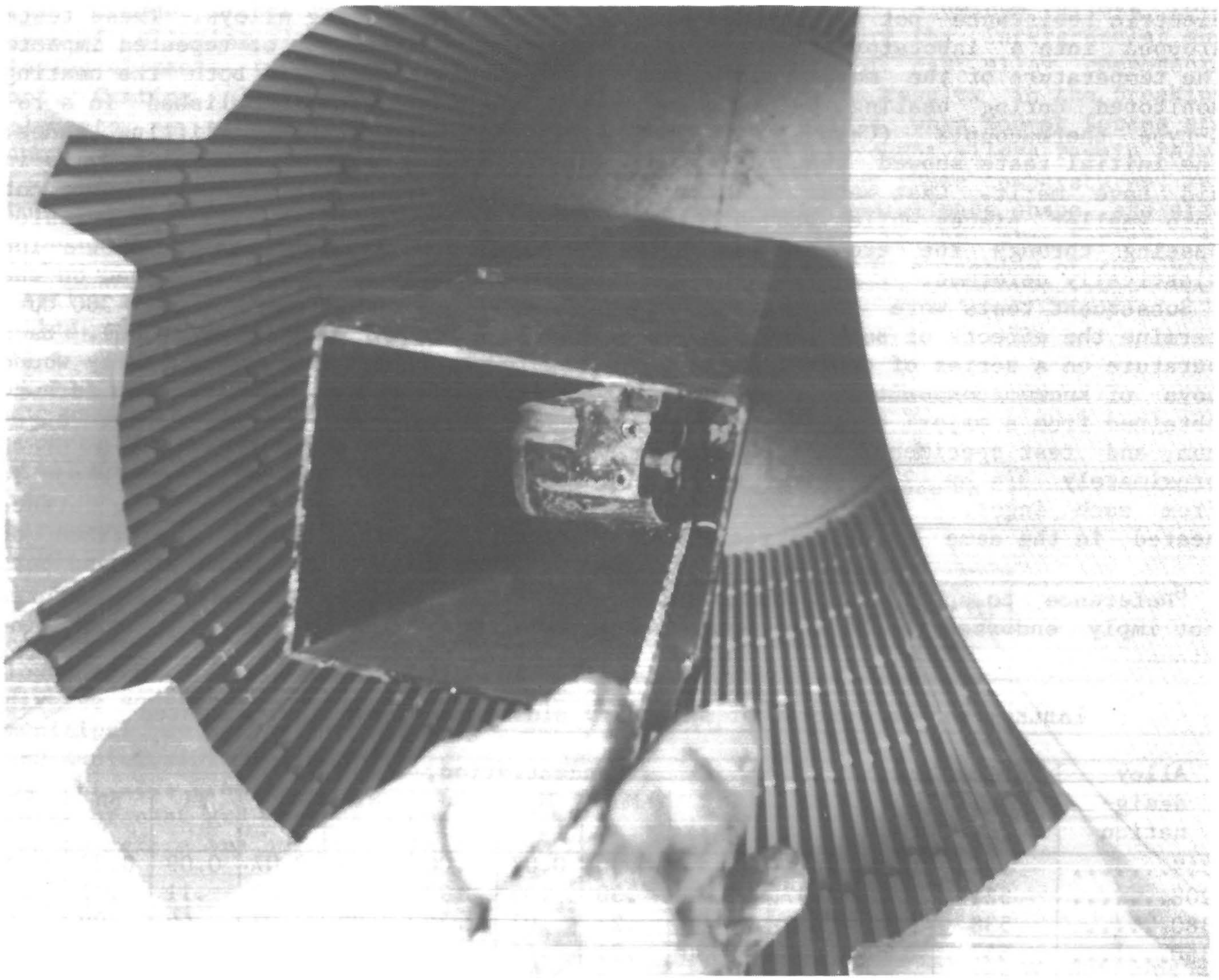

FIGURE 2. - Drop-test furnace.

TABLE 2. - Hand characterization of scrap aluminum separated from reject nonferrous fraction

Fraction	Distribution, wt pct				
	Total sample		Plus 1-in material		
	Minus 1 in	Plus 1 in	Cast	Wrought	Other[1]
1................	33	67	62	28	10
2................	27	73	65	32	3
3................	18	82	63	34	3
4................	37	63	72	25	3
5................	36	64	67	30	2
Average[2]......	30	70	66	30	4

[1]Rocks, rubber, etc. (mostly combustible).

[2]Approximate average total composition per 100 lb is 21 lb wrought (all plus 1 in), 76 lb cast (30 lb minus 1 in, 46 lb plus 1 in), 3 lb other.

cast-wrought material to be processed by hot-crushing. The undersize (cast) fraction could be added directly to the hot-crush cast product. The plus 1-in fractions were used for this hot-crush testing series. In these tests, temperatures of 500° to 580° C, in 20° C increments, and soak times in 1-h increments ranging from 1 to 6 h were used. Approximately 11 lb of mixed wrought and cast aluminum were used in each test. The oversize material remaining from the tests of 520° C and 540° C was subsequently reprocessed to evaluate the merits of multiple-stage heating, crushing, and screening. The plus 1-in material from processing at 520° C was reprocessed at 540°, 560°, 570°, and 580° C. Material from the 540° C test was similarly reprocessed at 560° C. The holding time in each case was 1 h.

The distribution of the cast aluminum product was evaluated with respect to soak time and temperature using two criteria. The first criterion was the quantity of cast aluminum that remained in the plus 1-in wrought fraction. The second criterion was the quantity of cast aluminum reduced to less than 12 mesh. Remelting aluminum scrap that is less than 12 mesh increases melting losses, flux requirements, and dross rate.

Finally, trials were conducted using multiple-stage (increasing temperature) processing to produce three fractions: wrought alloys, high-copper casting alloys, and low-copper casting alloys.

RESULTS AND DISCUSSION

The exploratory hot-crushing experiment, using scrap aluminum from a Utah automobile shredder, demonstrated the expected difference in thermomechanical behavior between wrought and cast aluminum alloys. A laboratory jaw crusher was set with a clearance of 1/2 inch. Wrought aluminum alloy pieces totaling 0.2 lb were heated to 580° C, held for 1 h, and passed through the crusher. All the wrought pieces essentially kept their original form and were only bent. They were all retained on a 1/2-in screen.

Cast aluminum alloys, totaling 0.7 lb were subjected to the same treatment except that the temperature was lowered to 550° C. All the cast pieces were fractured in the crusher and readily passed through a 1/2-in screen except for one piece. Chemical analysis showed that this casting alloy was one with low copper content. Excellent separation was also obtained when mixtures of wrought and cast alloys were heated to 565° C and crushed and subsequently screened at 1/2 in. The wrought pieces were flattened; the cast pieces were fragmented.

Due to thermocouple placement, the actual temperatures for the soak time and temperature experiment were lower than indicated. This made the measured temperatures appear higher than expected with respect to the solidus temperatures listed in table 1. Nevertheless, as the solidus temperatures increase through the series of alloys, longer soak times and higher temperatures are necessary for embrittlement.

Effect of Soak Time and Temperature

At 540° C, all samples (alloys 208, 319, 360, 380, and 413) retained good mechanical strength and ductility for the time periods tested. At 560° C, alloy 319 was the first to fragment, followed by alloys 208 and 380. As the temperature increased to 580°, alloys 319, 208, and 380 again were the fist to fragment; alloy 360 fragmented next at a longer soak time; and alloy 413 retained its ductility and strength. At 590° C, all sample alloys were brittle for both times tested. The time effect, while mainly one of achieving uniform temperature, is important. At 600° C, all samples exhibited the complete range of behavior, from ductile to actually melting, as a function of time (table 3).

These results are in agreement with published data on eutectic temperatures (9-10) and support the hypothesis that the mechanism of the reduction of mechanical strength and ductility of the casting alloys is softening or melting of intergranular eutectic regions. Eutectic melting, affecting areas between grains of a casting, occurs at different temperatures for different alloys. This is the solidus temperature for each alloy, the temperature above which liquid is first formed upon heating. The alloys evaluated cover a wide range of solidus temperatures.

Effect of Impact Energy and Soak Temperature

Effects of the parameters impact energy and soak temperature (simulating rotary kiln treatment) were investigated for alloy 380 using three samples taken from an automotive transmission housing. Results of drop tests indicated that increases in impact energy (height), number of cycles, and soak temperature result in increased fragmentation. However, increase in temperature had a much greater influence on fragmentation than did increase in impact energy due to the increase in drop height (table 4). The higher temperature would result in more liquid metal present relative to the amount of solid phase metal. This would greatly increase breakage. No fragmentation occurred for tests conducted at 515° and 530° C. Linear extrapolation indicates that the 545° C, 2-ft condition would require about 15 drop cycles for

TABLE 3. - Results of hammer mill tests using casting alloys

Alloy	Time, min		
	20	40	60
540° C:			
319..	Ductile...	Ductile...	Ductile.
208..	...do.....	...do.....	Do.
380..	...do.....	...do.....	Do.
360..	...do.....	...do.....	Do.
413..	...do.....	...do.....	Do.
560° C:			
319..	...do.....	Brittle...	Brittle.
208..	...do.....	Ductile...	Do.
380..	...do.....	...do.....	Do.
360..	...do.....	...do.....	Ductile.
413..	...do.....	...do.....	Do.
580° C:			
319..	([1]).......	Brittle...	Brittle.
208..	Ductile...	...do.....	Do.
380..	...do.....	...do.....	Do.
360..	...do.....	Ductile...	Do.
413..	...do.....	...do.....	Ductile.
590° C:			
319..	Not tested	Brittle...	Brittle.
208..	...do.....	...do.....	Do.
380..	...do.....	...do.....	Do.
360..	...do.....	...do.....	Do.
413..	...do.....	...do.....	Do.
600° C:			
319..	([1]).......	Not tested	Brittle; some melting.
208..	Ductile...	...do.....	Do.
380..	...do.....	...do.....	Do.
360..	...do.....	...do.....	Do.
413..	...do.....	...do.....	Do.

[1]Initial signs of embrittlement.

TABLE 4. - Results of drop tests using alloy 380

Drop height, ft	Temp., °C	Results
2..........	545	28 pct <1 in after 5 cycles.
3..........	545	60 pct <1 in after 5 cycles.
3..........	560	100 pct <1 in after 3 cycles.

all the material to fragment and pass a 1-in screen, whereas at the same temperature the 3-ft condition would require about 10 cycles. Only three cycles were required for the 560° C, 3-ft condition.

Material for the next sequence of tests was the aluminum concentrate produced by heavy-medium processing of the nonmagnetic fraction of automobile shredder reject. Prior to testing, this material was sized with a 1-in screen and hand characterized to determine the distribution of cast and wrought alloys in the two fractions (table 2). The minus 1-in fraction was composed almost exclusively of cast aluminum alloy. The plus 1-in fraction was the raw material for hot-crush processing.

The goal of this sequence of tests was to determine the conditions that maximize the cast aluminum alloy reporting to the minus 1-in, plus 12-mesh fraction, while minimizing the minus 12-mesh fraction. Results of tests using soak times ranging from 1 to 6 h and temperatures ranging from 500° to 560° C are listed in table 5. Testing was performed at 580° C, but results were not tabulated because significant melting occurred. The results show that the effect of time is negligible compared with that of temperature if the sample has been held at temperature long enough to become uniformly heated. In the test program, approximately 11-lb samples of aluminum concentrate were placed in a crucible monitored by a standard K-type thermocouple, brought to temperature, held for the desired period of time, and immediately discharged into the hammer mill. The hot-crush screened product fractions were plus 1 in, minus 1 in plus 12 mesh, and minus 12 mesh.

TABLE 5. - Size distribution of cast aluminum after single-stage processing,[1] percent

Soak time, h	Plus 1 in	Minus 1 in, plus 12 mesh	Minus 12 mesh
At 500° C:			
1.........	81	17	2
2.........	74	23	3
3.........	57	40	3
4.........	68	30	2
5.........	80	17	3
6.........	70	28	2
At 520° C:			
1.........	69	26	5
2.........	28	61	11
3.........	29	45	26
4.........	74	24	3
5.........	53	43	4
6.........	24	52	24
At 540° C:			
1.........	36	47	18
2.........	23	62	15
3.........	16	71	13
4.........	31	49	21
5.........	34	54	12
6.........	28	57	15
At 560° C:			
1.........	8	49	43
2.........	13	46	41
3.........	13	53	34
4.........	13	51	36
5.........	17	46	34
6.........	7	55	38

[1]Determined by hand characterization and screening.

Each product was weighed and visually inspected.

Results of hot-crush processing at 500° C indicate limited fragmenting of cast alloys regardless of soak time. The average value for cast alloy remaining in the plus 1-in fraction was 72 pct (table 6). A head-feed of scrap material having the average composition shown in table 2 would therefore be expected to be upgraded from 21 lb of wrought metal per 100 lb of starting mixed alloy to a wrought product (plus 1 in) of 21 lb of wrought alloy and 33 lb (72 pct of 46 lb) of cast alloy (table 7). This represents an upgrade from 21 pct wrought to 39 pct wrought.

TABLE 6. - Size distribution of original plus 1-in cast aluminum versus processing temperature

Temperature, °C	Plus 1 in	Minus 1 in, plus 12 mesh	Minus 12 mesh
SINGLE-STAGE PROCESSING,[1] wt pct			
500	72	26	2
520	46	42	12
540	28	57	16
560	12	50	38
MULTIPLE-STAGE PROCESSING, wt pct			
520-540	15	66	19
520-540-560	9	70	21
520-540-560-570	4	74	22
520-540-560-570-580	1	76	23
540-560	10	68	23

[1]Average of 6 tests in table 5.

TABLE 7. - Distribution of hot-crush products from each 100 lb of aluminum concentrate[1]

Temperature, °C	Wrought product, lb		Cast product, lb
	Wrought	Cast	
SINGLE-STAGE PROCESSING			
500	21	33	43
520	21	21	55
540	21	13	63
560	21	6	70
MULTIPLE-STAGE PROCESSING			
520-540	21	7	69
520-540-560	21	4	72
520-540-560-570	21	2	74
520-540-560-570-580	21	.5	75.5
540-560	21	5	71

[1]3-lb loss of organics during furnace operation.

Results from testing at 520° C indicate that the average mixed feed could be upgraded into a wrought fraction containing 21 lb of wrought alloy and 21 lb of cast alloy (50 pct wrought).

Processing at 540° C further improved the fragmentation of cast alloys. Cast material at this temperature was very sensitive to external forces and tended to break apart as the crucible contents were being discharged into the hammer mill. Using the same basis for comparison, the average feed composition, the wrought product produced at this temperature would contain 21 lb of wrought alloy and 13 lb of cast alloy (62 pct wrought). Figure 3 is a detailed flow sheet showing the results of this test.

Test results for processing at 560° C indicated considerable melting of aluminum eutectics with soak times greater than 2 h. This temperature appears to be the upper limit for single-stage processing of scrap aluminum. At 560° C, the wrought product would contain 21 lb of wrought alloy and 6 lb of cast alloy (78 pct wrought).

Two 1-h tests were conducted at 580° C. Bulk melting of the test samples confirmed that the temperature was above the maximum practical limit for single-stage processing of this particular sample of aluminum scrap.

Results of the multiple-stage processing experiments were similar to those obtained from single-stage processing.

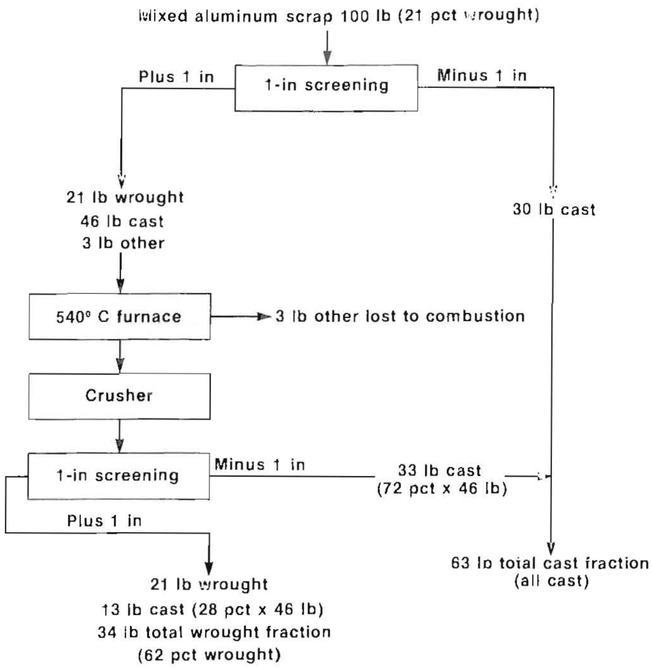

FIGURE 3. - Flow sheet showing results of hot-crush processing at 540° C.

However, there are several significant findings that are evident from tables 6 and 7. The amount of cast alloy reporting to the wrought fraction (plus 1 in) was 12 pct for 560° C single-stage processing, 10 pct for two-stage processing at 540° and 560° C, and 9 pct for three-stage processing at 520°, 540°, and 560° C. These results are not significantly different. However, the fines generation rate is 38 pct for single-stage, 23 pct for two-stage, and 21 pct for three-stage processing, while the desirable plus 12-mesh, minus 1-in fraction increases dramatically from 50 pct to 68 pct to 70 pct, respectively.

Single-stage processing has an apparent upper temperature limit of 560° C since excessive melting occurred at 580° C. For this reason, two additional tests were performed at 570° and 580° C, with the oversive left from reprocessing material from 520° through 560° C, to determine if a higher temperature limit is feasible when using multiple-stage processing. The results were very favorable, indicating a reduction of the cast alloys remaining in the oversize to 1 pct of the original cast portion, while the fines fraction was not significantly increased. The best wrought product therefore would be contaminated by only 2 pct casting alloy. No bulk melting was observed.

The distribution of cast alloys upon hot-crushing was not a function of soak time at the temperatures tested but rather of soak temperature (table 5). The cast oversize remaining after processing was reduced progressively by increasing the soak temperature. Multiple-stage processing resulted in the best separation of wrought from cast and also the least generation of fines in the cast product.

Chemical analyses of the products from hot-crush processing the oversize fraction of the aluminum concentrate are listed in tables 8-10. These analyses are of melt specimens taken from heats of representative samples of the fractions of concern. Hence these results represent the average composition of the respective fractions.

TABLE 8. - Chemical composition of products after single-stage processing

Treatment temp., °C	Concentration, wt pct				
	Cu	Fe	Mg	Si	Zn
CAST PRODUCTS, MINUS 1 in					
500............	3.4	0.9	0.3	11.1	5.4
520............	4.6	1.9	NA	8.7	3.5
540............	2.9	.8	1.6	11.1	3.1
560............	3.7	1.0	.9	9.9	4.6
WROUGHT PRODUCTS, PLUS 1 in					
500............	2.3	0.8	0.5	7.8	0.9
520............	1.5	.8	NA	4.8	NA
540............	1.3	NA	.1	2.5	.9
560............	1.6	.6	1.7	2.6	.8

NA Not available.

TABLE 9. - Chemical analysis of cast alloy product from multiple-stage processing

Temperature of last stage	Concentration, wt pct				
	Si	Cu	Fe	Mg	Zn
540° C.........	6.8	3.2	0.8	0.1	1.8
560° C.........	6.5	2.2	.9	.3	.8
570° C.........	5.5	.5	.6	.1	.3
580° C.........	4.6	.3	.4	.4	.5

TABLE 10. - Copper content of cast fraction product from multiple-stage processing

Source of sample	Temperatures, °C	Sample size, lb	Screen size, in	Cu in cast fraction, wt pct	
				After stage 1	After stage 2
Georgia.....	540, 575	5	1	2.7	0.5
Utah........	540, 575	5	1	2.8	.7
Maryland....	540, 575	5	1	2.7	.5
Do........	560, 610	400	2	3.0	.8

In table 8, the higher level of alloying elements, particularly silicon, in the cast (minus 1-in) product is consistent with the observed separation of cast and wrought alloy components. However, the zinc content of the cast fractions is too high, which is probably due to contamination by zinc diecasting pieces. The zinc diecasting alloys have solidus temperatures of approximately 380° C and melting points of less than 400° C. Therefore, these components will report to the cast fraction unless they are removed by a 390° C hot-crush step or by some other means. If present, 2000 or 7000 series wrought aluminum alloys would also report to the casting alloy fraction. This is fortunate because copper and zinc are penalty elements for most grades of wrought aluminun scrap. It is unlikely that these alloys, typically used in aircraft applications, would occur along with mixtures of pots and pans, storm windows, and automobile crusher rejects.

Multiple-stage processing not only results in lower fines generation, it also can result in a high copper-low copper separation within the cast fraction because of the difference in solidus temperatures for these alloys. Table 1 shows that a processing temperature of approximately 545° C would result in fragmentation of alloys with more than 3 pct copper, but those with less than 1 pct copper would retain their form. Small- and large-scale tests showed that this principle is a practical one. Tables 9 and 10 show the progressively lower amounts of copper present in the cast fraction with multiple-stage processing. The temperature measurements during the larger scale test were high due to thermocouple placement. A larger screen was used to achieve faster throughput.

In any full-scale application of these principles, temperature, crusher type and setting, and screen size should be optimized for each cast-and-wrought mixture to be processed. The economics of the proposed process is complex and would depend mainly on the percentage of wrought alloys in the feed material and the local prices for energy and scrap. If the mixed scrap (with sufficient wrought alloy present) could be heated, crushed, and screened for about a penny a pound, the process would be profitable at one or two stages. An increase in the price differential between cast and wrought scrap or the use of waste heat would increase profitability.

SUMMARY

Tests conducted on individual pieces of cast and wrought aluminum alloys demonstrated that the more brittle behavior of cast aluminum alloys at elevated temperatures can be used to separate mixtures of cast and wrought aluminum alloys. Further study using uniform samples of selected casting alloys resulted in the observation that the temperatures at which specific alloys become brittle closely parallel the solidus temperatures of those alloys. Liquid is first formed upon heating above the solidus temperature. This liquid is formed at the grain boundaries. When a liquid network is present in the grain boundaries, a metallic object is easily fractured upon impact, even if the object is almost completely solid. When a mixture of alloys is crushed at a temperature between the highest and lowest solidus temperatures of the alloys in the mixture, the alloys having a low solidus temperature will fracture readily; those having a high solidus temperature will either fracture to a lesser extent or only be plastically deformed. This effect was observed in binary alloys by Singer and Cottrell (9) where experiments covering aluminum alloys from 0 to 12 pct silicon showed that the sudden decrease in strength (as a function of temperature) corresponds very well with the solidus temperatures for the alloy series. The present experiments using the commercial aluminum casting alloys 208, 319, 360, 380, and 413 further demonstrated this trend. The reported data support the hypothesis that intergranular melting of the eutectic composition was responsible for the exhibited reduction in strength and is the basis for a practical technique for separating mixtures of cast and wrought aluminum alloys. Typical products from the process are shown in figure 4. The lower and upper temperature limits for a single-step hot-crushing operation, based on our mixed aluminum concentrate from automobile shredder rejects, are 520° C and 560° C, respectively. For single-stage processing, the cast content of the wrought product was progressively reduced with increasing temperature; however, the fines content of the cast fraction increased with increasing temperature. Multiple-stage processing at two or more temperatures results in better separation with proportionally lower production of fines, and provides a high and low pct copper separation within the cast fraction.

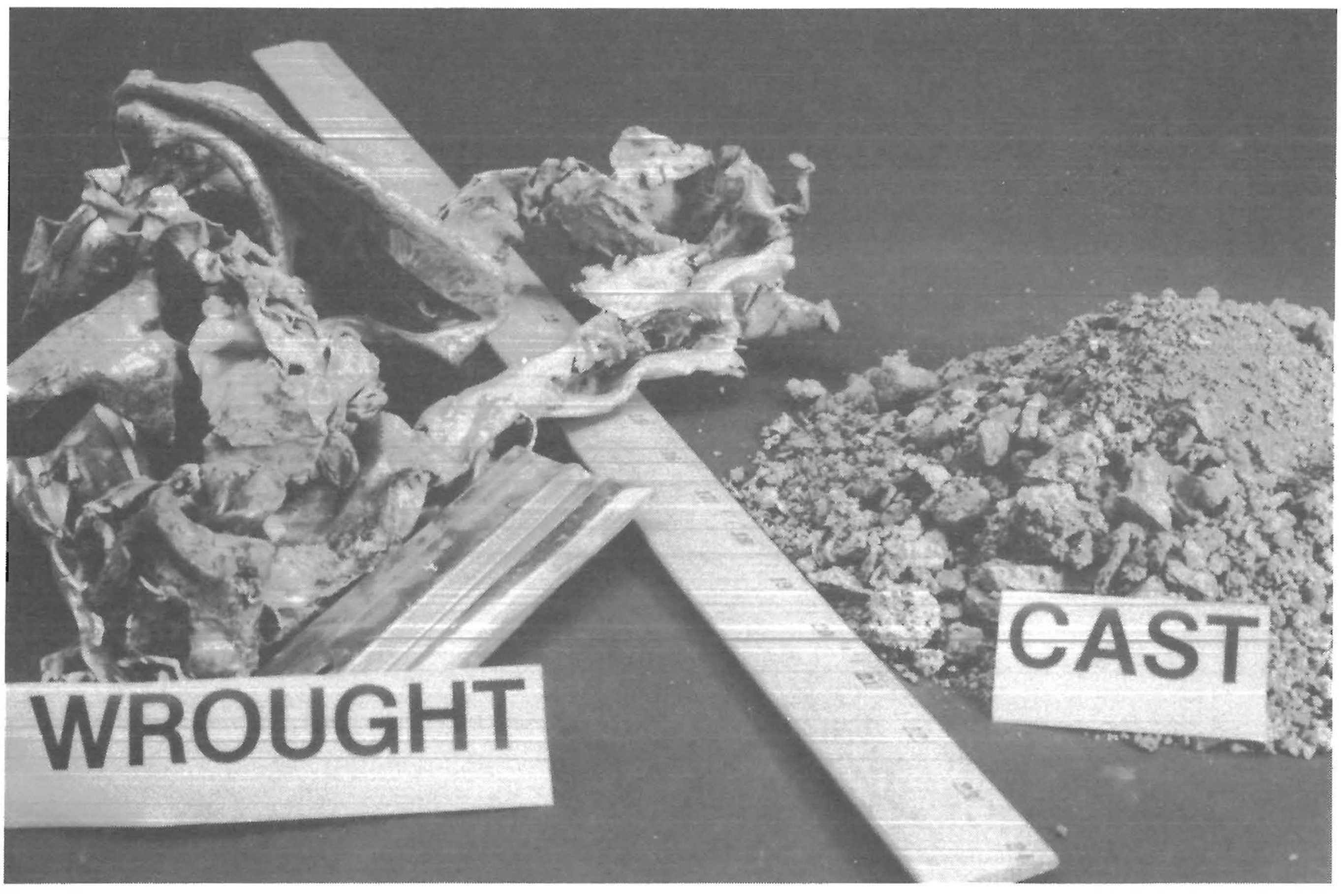

FIGURE 4. - Wrought and cast products.

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